Leading Community Risk Reduction

CO Poisoning from Portable Generators:

Preventing a Second Disaster Following a Hurricane.

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Appendices Not Included. Please visit the Learning Resource Center on the Web at http://www.lrc.dhs.gov/ to learn how to obtain this report in its entirety through Interlibrary Loan.

CERTIFICATION STATEMENT

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Abstract

This action research project looked at carbon-monoxide (CO) poisoning from portable generators following a major power outage. The problem was that during a major power outage following a hurricane, the Cape Coral (Florida) Fire Department responded to incidents of CO poisoning from the improper use of portable generators. Failure to research this problem may result in the needless loss of life or injury from CO poisoning from improper generator placement. The purpose of this research was to identify safe operating distances for portable generators and use the findings to create a television program to educate residents in an effort to reduce the community's risk of CO poisoning following a disaster. This study answered four questions. What were the inherent dangers associated with the use of portable generators? How common was the problem of CO poisoning from a portable generator following a disaster? What method(s) could the Cape Coral Fire Department use to communicate the dangers associated with portable generator use before, during, and after a hurricane? What was the minimum safe distance that a portable generator could be placed from a home to reduce the risk of CO poisoning? Through extensive literature review, research of others, and conducting four experiments using actual generators to establish safe operating distances this study determined fifteen-feet as the minimum safe distance to operate a portable generator from any opening of a home. The cumulative findings of this project culminated in a television program regarding generator safety to be broadcast locally on cable television. Future research should be conducted to further establish realistic environmental operating distances and seek technology advancements and fuels to reduce CO emissions from portable generators.

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Appendices

In 2005, the United States encountered the busiest hurricane season ever recorded. The magnitude of devastation dealt by Hurricane Katrina to New Orleans and the surrounding Gulf Coast areas in 2005, shocked even the most seasoned emergency managers and left all levels of government scrambling to be better prepared for future events related to natural and man-made disaster. It is during natural and man-made disasters; such as hurricanes, that massive electrical power outages are common due to the electrical distribution systems being devastated from the related disaster event. Today, many individuals throughout this nation have the financial means available to purchase and utilize a portable electrical generator to supply a limited amount of electrical power following a disaster-type event that causes a major electrical power disruption in service. It is during this post-disaster time period that the fire service responds to many incidents involving inadvertent carbon-monoxide (CO) poisonings related to the use of a portable electrical generator; which is the focus of this research project.

The problem is that during a major electrical power outage following a hurricane or tropical storm event, the Cape Coral (Florida) Fire, Rescue, and Emergency Management Service has responded to several incidents involving accidental CO poisoning by residents using portable generators improperly. Failure to research this problem may result in the needless loss of life or injury from CO poisoning as a result of improper portable generator usage. The purpose of this research is to identify safe operating distances near the home for portable generators and use the research findings to create a television program on the local government cable channel to educate the residents in an effort to reduce this community's risk of CO poisoning from portable generators following a major power outage from a hurricane, tropical storm, or other disaster-type event. This research study will utilize the action research method to answer the following questions. What are the inherent dangers associated with the use of portable generators? How common is the problem of accidental CO poisoning in the use of portable generators following disaster-type events? What method can the Cape Coral Fire, Rescue, and Emergency Management Service use to communicate to citizens about the dangers associated with portable electrical generator use before, during, and after a hurricane event? What is the minimum distance that a portable generator should be placed from the home to reduce the risk of accidental CO poisoning?

Background and Significance

On August 10, 2004, residents of Florida's gulf coast from the Florida Keys to the Panhandle were advised to stay informed on a developing tropical depression south of Cuba. Hurricane computer models predicted a northerly tract for Tropical Storm Charley with continued strengthening during the next seventy-two hours. On the evening of August 11, 2004 the storm had intensified into Hurricane Charley and the City of Cape Coral declared a Local State of Emergency which resulted in the Cape Coral Fire, Rescue, and Emergency Management Service activating the Emergency Operations Center (EOC). The National Hurricane Center in Miami, Florida continued to forecast a north-northeast tract with landfall expectancy of Hurricane Charley to occur within a fifty-mile radius of Tampa, Florida sometime on August 13, 2004. This same forecast tract of Tampa, Florida by the National Hurricane Center continued until approximately four hours before actual landfall occurred. When Hurricane Charley was one-hundred miles off the Southwest Florida coast in the Gulf of Mexico, it turned abruptly to the east with a newly forecasted landfall of Sanibel Island located in Lee County, Florida. The Centers for Disease Control and Prevention (CDC) reports, on August 13, 2004 at approximately 3:45 p.m. EDT, Hurricane Charley made landfall at Cayo Costa, Gulf of Mexico barrier island west of Cape Coral, Florida as a Category-4 storm, with sustained winds estimated at 145-mph (CDC: September 17, 2004). Hurricane Charley was the strongest hurricane to make landfall in the United States since Hurricane Andrew in August, 1992. The winds speeds in the City of Cape Coral were nowhere near the 145 mph wind speeds located near the eye of circulation; however they were strong enough to nearly totally destroy and disrupt major portions of the electrical power distribution system throughout the city for nearly eight days in some areas.

The City of Cape Coral, Florida had planned for just such a hurricane event and was well prepared to respond to the post-storm needs of the residents. One unexpected situation that developed that the Cape Coral Fire, Rescue, and Emergency Management Service did not anticipate were the growing numbers of accidental CO poisoning incidents from residents using portable generators. Though the City of Cape Coral did not experience any deaths associated with the wide-spread use of portable generators during the power outage, it did encounter many situations were residents were actively being poisoned by CO from generators; and some residents even required transport by ambulance to the hospital for treatment and observation.

When the very first case of CO poisoning from a portable generator was discovered, the Fire Chief quickly responded by establishing and equipping special teams of personnel from the fire prevention and education divisions. These teams traveled throughout the city looking for residents using generators and began testing for CO levels in and around their homes for the presence and buildup of this deadly gas. The resident was quickly educated about the dangers of improper generator placement and this remained the method of handling the situation of CO poisoning for the remainder of the power outage within the City of Cape Coral during this post-storm event. It is believed that a contributing factor to the early number of CO poisoning incidents from portable generators was directly related to information transmitted by local television broadcasters. Local television station WINK-TV, reported during a continual hurricane coverage broadcast that listeners should make sure generators were in a secure location due to reports of generator thefts beginning to be reported to local law enforcement agencies (Thome, 2004). Emergency Management officials quickly responded and worked with the local news media outlets to announce and clarify information that generators should never be located and operated anywhere indoors.

This research project will directly relate to the United States Fire Administration's operational objectives of promoting risk reduction and respond appropriately in a timely manner to emerging issues that face the fire service. This research project will investigate the dangers surrounding CO poisoning from portable generators and look for answers to reduce this community's risk of CO poisoning when the next disaster strikes. I plan to conduct this action research project utilizing a comprehensive and extensive literature review, examining research conducted by others, and conducting four experiments using actual generators to establish safe operating distances for portable generators near the home. The cumulative findings of this action research project will be culminated in a television program regarding generator safety to be broadcast locally on cable television.

Literature Review

In reviewing the literature, four specific areas were investigated related to portable generator usage to guide this action research project. These four areas included the dangers of CO gas, impact of CO on humans, historical CO poisoning from generator cases, and the detection, warning and notification regarding CO gas from portable generators.

The first research question asks, what are the inherent dangers associated with the use of portable generators? Portable generators are considered safe and effective when used correctly. When used incorrectly, portable generators can kill. The inherent dangers associated with incorrect use of portable generators include fire, electrocution, and burn injuries. However, the principal inherent danger and the leading cause of death associated with the incorrect usage of portable generators is inadvertent CO poisoning following some type of disaster that disrupts electrical power throughout the community. Although CO deaths from portable generators only account for a small percentage of the total CO deaths annually in the United States, there is a disturbing trend that indicates these deaths may be on the rise. In a report by the Consumer Product Safety Commission (CPSC) regarding portable generators found the number of generator-related CO poisoning deaths doubled from 18 deaths in 2001 to 36 deaths in 2003 (May 20, 2004). In another report, preliminary data by the CPSC show CO poisoning from generators in 2005 caused a record 58 deaths last year (O'Donnell, 2006). This rise in CO deaths from portable generators might just be the beginning of a worse problem to come here in the United States. In a study by Daley, Smith, Paz-Argandona, Malilay, and McGeehin, (2000) they discuss that decreasing price and increasing availability of generators may be factors causing increases in post-disaster CO poisoning from these type devices. In fact, according to an internal memo from Mary Donaldson with the CPSC (2004, April 12), sales of portable generators have been increasing since 2000. This major concern regarding these rising statistics and record CO deaths from portable generators is that every one of these deaths is preventable. In summary of the inherent dangers of portable generators and the rising number of CO poisoning cases each year, this research project will further the goal of attempting to reduce the risk of CO poisoning from these devices.

The impact of CO on humans can have deadly consequences if not detected or treated in-time. A major factor in CO poisoning is that humans are unable to detect the presence of CO gas with their natural senses. Montagna (1996) explains that CO is a colorless, odorless, and tasteless gas, is slightly lighter than air, with a specific gravity of 0.97 and has an explosive range of 12.5 to 74 percent. It is lethal in minutes at 1.28 percent in air and will asphyxiate long before it poses an explosion hazard. Many people believe simply opening doors and/or windows in their home will allow enough ventilation to operate a generator in a room or attached garage of their home. Previous research proves otherwise. Based on an environmental model developed by Earnest, Mickelsen, McCammon, & O'Brien, D. (1997), it would require more than 50 room-volume air exchanges per hour to keep exhaust from a five-horsepower gasoline engine operating in a 10,000 cubic-foot room from reaching 200 parts-per-million (ppm). Under the same conditions with only five air exchanges per hour, CO levels would accumulate above the 1,200ppm level, considered immediately dangerous to life and health after only ten minutes of continuous operation.

The statistics on CO poisoning in the United States are well documented. In one study by Cobb and Etzel (1991), it found that CO is responsible for more fatalities in the United States each year than any other toxicant. In January, 2005 the Director of the Georgia Poison Center in Atlanta stated CO is "the leading cause of poisoning death in America" (Gilbert, 2006). In another study recently conducted by the CPSC an estimated 10,200 people report to hospital emergency rooms each year for CO poisoning (Dunne, 2003). However, some experts disagree with this figure and argue the incidence of CO poisoning in the United States is much higher. The findings of Varon and Marik (1997) report the true incidence of CO poisoning is not known, since many non-lethal exposures go undetected. This study estimates that one-third of all cases of CO poisoning are undiagnosed. The reason that many CO poisoning cases go undiagnosed or unreported is related to the signs and symptoms that a person exhibits.

The signs and symptoms of CO poisoning listed by Dwyer, Leatherman, Manclark, Kimball, & Rasmmussen (2003) are confusion, dizziness, headache, eye irritation, upper respiratory irritation, fatigue, wheezing, bronchial constriction, persistent cough, increased frequency of angina in persons with coronary heart disease, and elevated CO blood levels, called carboxyhemoglobin (COHb). The signs and symptoms just listed are commonly thought of as harmless by many medical professionals when no other information regarding the patient is available. Vajani, Annest, Ballesteros, Gilchrist, & Stock (2005) discuss that most signs and symptoms of CO exposure are nonspecific (e.g., headache or nausea) and can be mistakenly attributed to other causes, such as viral illnesses. Undetected or unsuspected CO exposure can result in death. Montagna (1996), states in his work that CO is known as "the great imitator" because a mild exposure can mimic the flu, causing a slight headache, nausea, vomiting, and fatigue (pg. 3). These symptoms of CO exposure are often misdiagnosed by residents as well as doctors in hospital emergency rooms. Simply not recognizing the signs and symptoms of CO exposure is not the only factor that makes it so lethal.

Inhalation or breathing is how CO enters the body. Probably the greatest danger associated with CO gas explains, Deputy Chief, William Shouldis of the Philadelphia, (PA) Fire Department is that individuals, “cannot see it, taste it, or smell it. It is nonirritating. There are few visible warnings of this hidden hazard. CO exposure is often considered a silent killer” (pg. 1). The silent killer term is given because individuals simply do not realize they are being exposed to CO gas because the senses of the human body do not detect it. Once in the lungs, CO is absorbed into the bloodstream forming COHb which binds to the red blood cell at the exact same receptor site as the oxygen molecule, and thus, prevents much-needed oxygen from being carried to the cells throughout the body (Montagna, 2003). The medical study by Varon and Marik (1997) agree that the most clear-cut mechanism by which CO toxicity occurs is competitive binding to the hemoglobin heme groups on the surface of the red blood cell. Research has shown that CO is 240 times more likely to be absorbed by the hemoglobin than oxygen. This reduced-level of oxygen being delivered to the cells throughout the body causes the breathing rate to increase, which further complicates the matter in which Montagna (1996) describes as “a one-two punch that can be fatal once the COHb level reaches 50 percent to 70 percent” (pg 2). Symptoms can vary between individuals for those who are similarly exposed to CO.

Medical treatment for individuals suffering from CO exposure or poisoning can vary depending on health factors, length of time and the concentration of CO exposure. The very first step is to remove the patient (s) to the exterior of the home with open-air ventilation. Any patient that presents with any of the signs and symptoms listed earlier should be placed on supplemental oxygen by emergency responders and transported to the hospital for observation and blood work. Using good patient assessment skills in recognizing the signs and symptoms of CO poisoning combined with quickly testing the atmosphere the patient was in with a CO metering device is the best method to determine if transport is necessary. In the study by Varon and Marik (1997) the mean half-life of COHb (CO level in arterial blood) is 320 minutes in young healthy volunteers on room air. This means that it took these individuals on average 320 minutes to reduce their level of CO within the bloodstream by one-half. The administration of one-hundred percent oxygen reduces the half-life to 80.3 minutes, while 100% oxygen at three atmospheres using a hyperbaric chamber will reduce the half-life to 23.3 minutes. This study indicates that a patient with moderate to severe CO toxicity will benefit if they can be treated in a medical facility with a hyperbaric treatment chamber. The hyperbaric chamber is best known for treating the medical condition of decompression illness seen in diving accidents, commonly referred to as the bends. There is recent medical evidence that suggests hyperbaric treatment improves patient outcomes when in one study (see Weaver, Hopkins, Chan, Churchill, Elliott, Clemmer, et al. 2002) it was found that those patients that received hyperbaric treatment for CO poisoning had better recovery results compared to those that did not receive hyperbaric treatment.

There are segments of the population that are more susceptible to CO poisoning than others. Montagna (2003) explains that small children have smaller body sizes and faster metabolism. The elderly often have preexisting medical problems. Both are more adversely affected by CO poisoning than normal healthy adults are. When a pregnant woman is exposed to CO, her unborn child will be more severely affected than the mother. Research conducted by Vajani et al. (2005) found from 2001 to 2003, males were 2.3 times more likely to die from CO poisoning. The nonfatal rate for CO exposure was highest for children aged ≤4 years, whereas the CO death rate was highest for adults aged ≥65 years. Adults aged ≥65 years accounted for 23.5% of CO poisoning deaths. With the data that exists related to CO poisoning in this country, generators account for only a small portion of the injuries and death.

The literature was also reviewed to answer the second research question regarding how common the problem of accidental CO poisoning from portable generators was following a disaster-type event. There have been many studies that looked at post-storm environments and specifically tracked CO exposure and poisoning incidents. Data shows that most CO poisoning in the United States do not occur from portable generators operating in an area just devastated by a hurricane. Vajani et al. (2005) found the annualized incidence of fatal and nonfatal CO exposures from 2001 to 2003 occurred more often during the fall and winter months; with the highest numbers occurring in December with 56 fatal and 2,157 nonfatal exposures and January had 69 fatal and 2,511 nonfatal exposures. The annualized incidence was substantially lower during the summer months common to hurricanes, with 21 fatal and 510 nonfatal exposures during June and 22 fatal and 524 nonfatal exposures occurring in July. Major storms seemed to be the major cause of power outages and resulting deaths associated with CO poisoning form portable generators. Relevant data was collected and reviewed from 1993 to present in an attempt to present the severity of the problem of CO poisoning from portable generators during disasters. In the following pages are the summary of the grim statistics regarding CO deaths from portable generators.

On January 20, 1993 a major winter storm struck the Puget Sound area of western Washington State interrupting electrical power for approximately a quarter-million residents for four days following the storm. During this four day period CO poisoning was a major health consequence. According to the CDC, forty-four patients representing 17 separate incidents from January 20 to 25 were included in the study (see February 19, 1993). Within 9 hours of the onset of the storm, patients began seeking medical care related to CO exposure. In all, forty-four patients were seen in emergency rooms and 24% (10 patients) were from portable generators as the sole source of the CO poisoning.

The State of New York was struck by a massive ice storm in January 1997 that knocked out power to almost 300,000 residents (see Downey, 1998). Six counties were declared disaster areas at the time by President Clinton. A massive mutual-aid plan involving 500 fire departments and more than 5,000 firefighters was enacted and responded to assist during this disaster. Almost half of the storm-related fatalities were caused by CO poisoning. Throughout the duration of the five-day incident numerous responses were for the continual problem of CO poisoning.

In early January 1998, a severe ice storm struck the northeastern United States and southeastern Canada. On January 7, the storm struck the State of Maine disrupting electric power service to over 600,000 individuals for up to two weeks. Following this storm, a study was conducted regarding an outbreak of CO poisoning in Maine after this major ice storm (see, Daley et al. 2000). The 100 confirmed cases of CO poisoning occurred in 42 exposure incidents. A generator was the sole CO source in 27 incidents, associated with eight hospital admissions and five requiring specialized hyperbaric oxygen treatment and one death. Every incident occurred in or around the home; with the strongest risk factor associated with CO poisoning from a gasoline powered generator was incorrect placement.

On September 21, 1998, Hurricane Georges struck Puerto Rico with wind speeds reaching 115 mph and left one-million residents without electricity. In all, two deaths were reported from CO poisoning and two other were hospitalized from portable generators (see, CDC October 30, 1998). Community education efforts were initiated immediately after the storm, and a CO fact sheet was prepared and distributed to residents and it is believed this reduced the incidence of CO related illnesses.

December 4, 2000 Mecklenburg County, North Carolina with a population of 722,367 was hit by a severe winter ice storm that caused 78.9% of the county households to lose power for up to nine days. There were a total of 161 CO exposure cases reported during this study. The CDC (March 12, 2004), reported among the cases, 124 had symptomatic poisoning (77.0%), including 25 (15.5%) with severe poisoning and one death. Local hospital emergency rooms treated 56 cases of CO poisoning during the nine day period. Portable generators accounted for 41 (74.5%) of these cases.

According to the CDC (September 17, 2004), Hurricane Charley struck on August 13, 2004 and was responsible for 31 deaths throughout the State of Florida. Of the 31 deaths, three (10.3%) were a direct result on CO poisoning from portable generators. In

2004, Hurricane Charley was just one of four major hurricanes that struck the State of Florida.

In Florida, the CDC collected data and studied the specific CO poisoning cases from portable generators during the 2004 hurricane season (see, CDC: July 22, 2005). During the four major hurricanes that struck Florida during August 13 to September 25, 2004, power outages occurred in several million homes throughout Florida. In this particular study, the misplacement of portable gasoline-powered generators (e.g., indoors, in garages, or outdoors near windows) was responsible for nearly all CO exposures. A total of 167 persons had nonfatal CO poisoning diagnosed during the study period, representing a total of 51 separate exposure incidents. Six deaths occurred from CO poisoning during the study period directly related to the misplacement of portable generators.

In 2005, the CDC conducted two separate medical studies specifically related to CO poisoning following major hurricanes in the Gulf Coast region from Texas to Alabama (see CDC, October 7, 2005 & CDC, March 10, 2006). The first study involved CO poisoning patients following Hurricane Katrina in Alabama, Louisiana, and Mississippi from August through September 2005. In this CDC study (2005), a total of 51 cases of CO poisoning were reported by hospitals with hyperbaric oxygen facilities. These cases included 46 nonfatal CO poisoning cases and five deaths. Among the nonfatal cases, sixteen occurred in Louisiana, twenty-four in Alabama, and six in Mississippi. The source of exposure for all but one of the nonfatal cases was CO exhaust from a portable generator. The incident in which four deaths and one nonfatal CO poisoning occurred involved use of a generator in a house. The single death with two nonfatal CO poisoning cases involved the use of a generator in a garage. The locations of the generators for the other cases were: under a deck (28.6%), near a window (26.2%), in a shed (16.7%), in a garage (11.9%), in a carport (9.5%), and in a basement (7.1%). The second study by the CDC (see, March 10, 2006), examines Alabama and Texas following Hurricanes Katrina and Rita. These two major hurricanes caused approximately 4 million households to lose electrical power. This study identified 27 incidents of CO poisoning resulting in 78 nonfatal cases and 10 deaths in hurricane-affected counties in Alabama and Texas, nearly all of which were caused by gasoline-powered generators. Most of the generators were placed outside but close to the home to power window air conditioners or connect to central electric panels. In this study, a portable generator was responsible for 25 (93%) of the 27 incidents. Of the other two cases, one involved a fixed generator and one involved a portable gas stove. Generators placed outside were an average of 3.2 feet away from the home. To summarize the literature related to previous cases of CO poisoning from portable generators and clear indication the problem continues to grow; this research project has merit and value to reduce the risk associated with CO poisoning and generators.

Much progress has been made in educating the public using a portable generator in areas affected by major power outages to have a CO detector inside their home with battery backup to ensure operation. Without the use of these simple CO detector devices, individuals would have no way of knowing if lethal CO gas is reaching dangerous levels around them. Measured in the air in parts-per-million (ppm), CO exposure of 800ppm for 45 minutes can cause flu-like symptoms, while exposure to the same for three hours can cause death. It is for this reason that humans must rely on proper placement of their portable generator and use a CO detector to ensure their safety while operating a generator.

Currently, all CO alarms manufactured in the Unites States are required to meet the requirements of Underwriter's Laboratory (UL) 2034 (requirements for home CO alarms). Dwyer et al. (2003) list the current UL 2034 listing:

> After October 1, 1998, UL 2034 listed CO alarms must measure and alarm when CO is: 30ppm for 30 days, 70ppm for no more than 189 minutes before alarming (may alarm as early as 60 min.), 150ppm for no more than 50 minutes before alarming (may alarm as early as 10 min.), 400 ppm for no more than 15 minutes before alarming (may alarm as early as 4 min.), and have a manual reset that will reenergize the alarm signal within six minutes if the CO concentrations remain at 70ppm or greater (pg 32).

Not everyone was in agreement for these newer UL 2034 standards revised in October, 1998. Some advocates and consumer groups feel the 1994 changes in UL 2034 have jeopardized public safety. These consumer groups are advocating newer models specifically designed for particularly sensitive populations such as an infants or someone with congestive heart problems or breathing problems that may suffer chronic ill effects from lower levels of CO not detected by the new UL 2034 standards (see, Dwyer et al. 2003). The current version of UL 2034 standard from October, 1998; which is less stringent than the original version from 1992, resulted from the tremendous number of false alarms that fire departments were responding to from the first-generation of CO alarm detectors. Montagna (1996) reports that in December 1994, the Chicago (IL) Fire Department responded to 1,851 CO detector alarms in a 24-hour period. For reasons such as this, the CO alarm manufacturing industry was forced to make an alarm that was less-sensitive and more-reliable to every day life situations.

Currently, three types of CO alarm technologies are employed in the United States. These include Biomimetic (gel-cell), Semiconductor, and Eletrochemical (see Montagna, 1996). Biomimetic detectors use synthetic hemoglobin that absorbs CO in much the same way as hemoglobin and has an expected life of ten years. Semiconductor CO detectors measure molecules that accumulate on the electronic sensor are highly selective to CO gas that alarm at levels near 100ppm with a life expectancy of five to ten years. Electrochemical technology is a relative newcomer to the home CO detector marketplace. It has a data-logging capability and can download CO activity for the preceding eight days to the alarm. It has a life expectancy for five to ten years as well.

Emergency responders faced with a post-disaster environment with major power disruptions must assume that the majority of residents within their jurisdiction will not have battery-operated CO alarm detectors present. How then, will emergency responders be able to quickly determine if CO gas is present and at what levels? Aside from the most-obvious of situations, responders will be unable to determine CO levels without specialized equipment. At a minimum, this specialized equipment should consist of atmospheric monitoring or measuring equipment that can determine the presence and concentration of oxygen and CO gas. There are many personal atmospheric measurement and monitoring devices available to emergency responders at reasonable costs in use today and due to the limitations of this study, these monitoring devices cannot be discussed in detail here. However, the emergency responder must be thoroughly trained on each particular CO monitoring or measuring device used within their respective agency and be trained and competent in the use of self-contained breathing apparatus (SCBA) should a contaminated atmosphere be discovered during recovery and response operations. The United States Environmental Protection Agency (EPA, 2000), has established that residential levels of CO are not to exceed 9ppm over an eight-hour average. In addition, the EPA has established the standard by which all CO monitoring or measuring equipment must achieve. The EPA-designated reference methods (see, EPA, 2000), are automated methods utilizing the nondispersive infrared (NDIR) technique, generally accepted as being the most reliable, continuous method for the measurement of CO in ambient air. The official EPA reference methods (Code of Federal Regulations, 1991a) include eleven reference methods designated for use in determining compliance for CO gas. No equivalent method using a principle other than NDIR has been designated for measuring CO in ambient air. Personal CO measurement or monitoring equipment devices are designed to be worn on the outside of the outermost garment of the emergency responder to constantly monitor the atmosphere surrounding the emergency responder. These devices are used by emergency personnel to quickly sample the immediate atmosphere of a home suspected of being contaminated with CO gas from a portable generator. One other item that emergency responders can use in suspecting CO poisoning is described by Varon and Marik (1997) where the occurrence of an illness in household pet(s) concurrent with or just preceding the onset of a patient's own illness should alert to the possibility of CO poisoning. Due to their smaller size and in general higher metabolic rates, pets may be more obviously and more severely affected by CO intoxication than their owners.

The third research question asks, what methods can the Cape Coral Fire, Rescue, and Emergency Management Service use to communicate to citizens about the dangers associated with portable electrical generator use before, during, and after a hurricane event? There are various methods that can be used before a storm to educate citizens regarding the dangers of CO poisoning from improper placement of portable generators. These communication methods include printed hurricane preparedness literature, public speaking engagements, and public education efforts. Some methods may even go to the extreme as mentioned by the CDC, where in Mecklenburg County, North Carolina a public health ordinance was adopted to require CO detectors in the majority of all residences to prevent CO poisoning (March 12, 2004). To reduce the risk of CO poisoning in Cape Coral, a new approach will be utilized. To adapt to modern communication methods, a new final product of this research study will be to develop a local governmental cable-television program regarding portable generators to be televised to the citizens of Cape Coral before a storm hits.

During the storm impact, little can be done to communicate the dangers of CO poisoning from generators. During this dangerous time period of a land-falling hurricane the priority must be entirely focused on communicating life-saving instructions to the public via radio and television. Immediately following the storm, printed information bulletins (see Appendix A) will be distributed and the atmosphere sampled for CO gas by specialty teams of fire department personnel with air monitoring equipment at every home located with portable generators in operation. This method proved effective during Hurricane Georges in 1998 where community education efforts were initiated immediately after the storm, and a CO fact sheet was prepared and distributed to residents and is believed to have reduced CO related illnesses (see, CDC October 30, 1998). The method of team deployment is also similar to those described in previous disasters (Downey 1998, Varon & Marik 1997, and Daley et al. 2000), where personnel located portable generators related to poisonous CO gas.

At the federal level, the Federal Emergency Management Agency (FEMA) with the United States Fire Administration (USFA) has joined with the CPSC in announcing a new document to help first responders to residential carbon monoxide incidents. This recent document was discussed in detail (Shouldis, 2004), and titled: Responding to Residential Carbon Monoxide Incidents – Guidelines for Fire and Other Emergency Responders, which is available online at either agency's website. This document is designed for the emergency responder, but both FEMA and CPSC are targeting the average citizen as well regarding portable generators and CO poisoning. In a FEMA news release (January, 2003), the CPSC and FEMA announce that they have joined forces once again to warn residents that using gas-powered generators indoors or in attached garages brings the deadly risk of CO poisoning. Following Hurricane Katrina, FEMA (September 17, 2005) had a news release in the Baton Rouge, Louisiana region regarding portable generators. Bill Lokey, FEMA's federal coordinating officer advised residents that, "The use of a generator or any gas-powered tool inside a house can be deadly, FEMA wants to warn residents that carbon monoxide can be a silent killer" (pg.1). With the approach of the 2006 hurricane season, UL and CPSC have launched a generator safety campaign to educate consumers about the dangers of portable generators. To reach consumers with this information, CPSC has developed a new warning label for all newly manufactured generators to be sold in the United States (see Appendix B). The

CPSC (see 2006, May 24) announced that UL has adopted the same label in its new procedures for certifying portable generators. Any manufacturer that wants a UL certification will have to place a new warning label on its generators.

To summarize the literature regarding methods to inform the public before, during, and after a storm regarding portable generators and CO poisoning, pursuing a television program to educate residents in this action research project seems promising. Residents must be informed with as many methods as possible to get the message out regarding CO poisoning and generators. This information may be put to use sooner than expected.

Following the record-breaking year of 2005 which contained twenty-eight storms, including fifteen hurricanes, the National Oceanic & Atmospheric Administration (NOAA) predicts a very active 2006 north Atlantic hurricane season. For the 2006 north Atlantic hurricane season, NOAA (2006) is predicting thirteen to sixteen named storms, with eight to ten becoming hurricanes, of which four to six could become a major hurricane of Category-3 strength or higher. Max Mayfield, director of NOAA's National Hurricane Center in Miami, Florida announced (NOAA 2006), "Whether we face an active hurricane season, or a below-normal season, the crucial message is the same: prepare, prepare, prepare. One hurricane hitting where you live is enough to make it a bad season," (pg.1).

In summary of the literature reviewed related to CO poisoning and attempts at its prevention, many authors acknowledged the need for further studies in this area on how to prevent future tragedies. Influenced by these previous works and the knowledge of the inability of humans to detect the presence of CO gas and its potential to kill, this action research project will further the understanding and knowledge base of research into CO poisoning by attempting to identify safe operating distances for portable generators and communicate these findings to the public in a local television program format.

Procedures

The procedures related to answering the first three research questions were accomplished by conducting a comprehensive literature review. This extensive literature review began on the campus of the National Fire Academy in Emmitsburg, Maryland in March 2006. In Florida, the comprehensive literature review continued using a computer search of the internet to obtain several articles and studies related to previous CO poisoning cases and portable generators. In addition, the libraries of Lee County, Florida, Edison Community College, and Florida Gulf Coast University were visited to research additional articles, conduct inter-library loans, and obtain information related to previous research studies.

With the comprehensive literature review completed, the original research element of this action research project was designed and developed to conduct four actual experiments using portable generators around residential occupancies to obtain data in identifying safe operating distances for portable generators to answer the final research question to be included in the final television program.

Experiment 1

The first generator experiment took place on August 9, 2006 at 08:00 within the boundaries of the city of Cape Coral at a single-family residence. The temperature was 76-degrees, winds were calm, 75 percent humidity, barometric pressure 30.09 and rising, and dew point 83 percent. The structure elevation was 8.89 feet above sea level located on an eighty by one-hundred-forty-five foot residential lot located on a freshwater canal to the rear of the structure. The residential structure was built in 1989, with 2,838 square-feet under roof-truss. The home was concrete-block exterior walls with stucco exterior surface. This structure incorporated a two-car garage into the design with an interior door leading from the garage into the living area. The front door entry way and rear lanai areas were both under truss and enclosed by aluminum frame with screen. All exterior windows were of glass with an aluminum awning overhanging each window.

Apparatus

The portable electrical generator used for the source of the CO gas in this study was model YG-4000D, manufactured by Yamaha (see Appendix E). This portable generator was powered by 87-octane unleaded gasoline. Two of the generator outlets each had a fifty-foot standard electrical extension cord attached that powered two standard-type appliances; a chest-type freezer and standard residential refrigerator. The atmospheric gas-monitor used in this study was supplied by the Cape Coral Fire, Rescue, and Emergency Management Service. The gas-monitor device was the M40 multi-gas monitor, manufactured by Industrial Scientific (see Appendix C) and measures the CO gas presence in the atmosphere by parts-per-million (ppm). The timed experiments utilized a standard digital stopwatch.

Procedure

Five specific sites were selected at this location to operate the portable generator and take CO-gas level readings at specific time intervals. Prior to starting the portable generator, the atmosphere was tested to make sure the presence of CO-gas was not present prior to beginning the test. After ensuring CO-gas was not present, the generator was started and CO-gas levels were measured at intervals of one, five, fifteen, and thirty minutes.

Location one had the portable generator located on the floor of the two-car garage with the garage door in the fully-open position. This placed the generator 7.50 feet from the door leading into the living area of the structure. The CO-gas level measurement was obtained at this door two-feet in height from the garage floor at the time intervals mentioned above. Location two had the portable generator located on the floor of the two-car garage with the garage door opened only one-foot from the fully-closed position. This placed the generator 7.50 feet from the interior door leading from the garage into the living area of the structure. The CO-gas level measurement was obtained at the same door two-feet in height from the garage floor at the time intervals mentioned earlier. Location three had the portable generator located on the floor of the front porch entry way. The dimensions of this front entry were 9.5 feet deep, 5.5 feet wide and 8.5 feet high of which half was enclosed by screen. The generator was located six feet from the front door leading into the living area of the home. The CO-gas level measurement was obtained at front door two-feet in height from the floor at the time intervals mentioned earlier. Location four had the portable generator located on the floor within the enclosure of the rear lanai. The dimensions of this location were 10 feet deep, 28 feet wide, and 9 feet high enclosed by screen. The closest opening to the home consisted of a sliding-glass door was 7.9 feet from the portable generator. The CO-gas level measurement was obtained at the door two-feet in height from the lanai floor at the time intervals mentioned earlier. Location five had the portable generator located on the ground on the exterior of the home. It was placed at a distance of fifteen feet from an exterior bedroom window. The CO-gas level measurement was obtained at four-feet in height at the glass of the window at the time intervals mentioned earlier. This research may have limitations in the ability to exactly replicate or duplicate this experiment elsewhere by the fact that this was conducted outside in an uncontrolled environmental setting.

Experiment 2

The second generator experiment took place on August 9, 2006 at 14:30 within the boundaries of the city of Cape Coral at a single-family residence. The temperature was 94-degrees, winds southeast at 9 mph, 79 percent humidity, barometric pressure 32.08 and rising, and dew point 57 percent. The structure elevation was 11.89 feet above sea level located on a standard eighty by one-hundred-twenty-five foot residential lot. The residential structure was built in 1981, with approximately 2,630 square-feet under roof-truss. The home was concrete-block exterior walls with stucco exterior surface. This structure incorporated a two-car garage into the design with an interior door leading from the garage into the living area. The rear lanai area was not under roof truss, but did have an aluminum pan roof over a portion of the lanai with the remaining area under an aluminum frame screened pool cage. Access from the rear lanai to the living area was via a two panel sliding-glass door. All exterior windows were standard glass.

Apparatus

The portable electrical generator used for the source of the CO gas in this study was model number YG-4000D, manufactured by Yamaha (see Appendix E). This portable generator was powered by 87-octane unleaded gasoline. Two of the generator outlets each had a fifty-foot standard electrical extension cord attached that powered two standard-type appliances; an upright freezer and a standard residential refrigerator. The atmospheric gas-monitor used in this study was obtaining by the Cape Coral Fire, Rescue, and Emergency Management Service. The gas-monitor device was the M40 multi-gas monitor, manufactured by Industrial Scientific (see Appendix C) and measures the CO gas presence in the atmosphere by parts-per-million (ppm). The timed experiments utilized a standard digital stopwatch.

Procedure.

Five sites were selected at this location to operate the portable generator and take CO-gas level readings at specific time intervals. Prior to starting the portable generator, the atmosphere was tested to make sure the presence of CO-gas was not present prior to beginning the test. After ensuring CO-gas was not present, the generator was started and CO-gas levels were measured at intervals of one, five, fifteen, and thirty minutes.

Location one had the portable generator located on the floor of the two-car garage with the garage door in the fully-open position. This placed the generator six feet from the door leading from the garage into the living area. The CO-gas level measurement was obtained at the door two-feet in height from the garage floor at the time intervals mentioned earlier. Location two had the portable generator located on the same garage floor with the garage door opened only one-foot from the fully-closed position. This placed the generator six feet from the interior door leading from the garage into the living area of the structure. The CO-gas level measurement was obtained at the interior door two-feet in height from the garage floor at the time intervals mentioned earlier. Location three had the portable generator located on the front porch walk way. There was a small screened entryway measuring five feet wide, fourteen feet deep, and ten feet high. The generator was located eleven feet from the front door leading into the home. The CO-gas level measurement was taken at the front door two-feet in height from the floor at the time intervals mentioned earlier. Location four had the portable generator located on the floor within the enclosure of the rear lanai pool area. The dimensions of this location were thirty-two feet deep, forty-eight feet wide, and fourteen feet high enclosed by screen. The closest opening to the home was the sliding-glass doors overlooking the pool that were nine feet, two inches from the portable generator. The CO-gas level measurement was obtained at the door four-feet in height from the lanai floor at the time intervals mentioned earlier. Location five had the portable generator located on the ground on the exterior of the home. It was placed at a distance of fifteen feet from an exterior bedroom window. The CO-gas level measurement was obtained at four-feet in height at the glass of the window at the time intervals mentioned earlier. This research may have limitations in the ability to exactly replicate or duplicate this experiment elsewhere by the fact that this was conducted outside in an uncontrolled environmental setting.

Experiment 3

The third generator experiment took place on August 10, 2006 at 09:30 within the boundaries of the city of Cape Coral at a single-family residence. The temperature was 76-degrees, winds southeast at 6 mph, 73 percent humidity, barometric pressure 36.08, and dew point 72 percent. The structure elevation was 9 feet above sea level located on an eighty by one-hundred-twenty-five foot residential lot located on a saltwater canal to the rear of the structure. The residential structure was a single-family executive-style home built in 1997, with approximately 3800 square feet under roof-truss. The home was concrete-block exterior walls with stucco exterior surface. This structure had a two-plus car garage incorporated into the construction of the home with an interior door leading from the garage into the living area. The rear lanai pool area had a large portion under truss, with the remaining area having an attached aluminum framed screen pool cage. All exterior windows were of standard glass.

Apparatus

The portable electrical generator used for the source of the CO gas in this study was a Pro-Series 6500, manufactured by Coleman (see Appendix D). This portable generator was powered by 87-octane unleaded gasoline. Two of the generator outlets each had a fifty-foot standard electrical extension cord attached that powered two standard residential refrigerators. The atmospheric gas-monitor used in this study was obtained from the Cape Coral Fire, Rescue, and Emergency Management Service. The gas-monitor device was the M40 multi-gas monitor, manufactured by Industrial Scientific (see Appendix C) and measures the CO gas presence in the atmosphere by parts-per-million (ppm). The timed experiments utilized a standard digital stopwatch.

Procedure

Five sites were selected at this location to operate the portable generator and take CO-gas level readings at specific time intervals. Prior to starting the portable generator, the atmosphere was tested to make sure the presence of CO-gas was not present prior to beginning the test. After ensuring CO-gas was not present, the generator was started and CO-gas levels were measured at intervals of one, five, fifteen, and thirty minutes.

Location one had the portable generator located in large garage on the floor with the garage door in the fully-open position. The generator was placed ten feet from the door leading into the living area from the garage. The CO-gas level measurement was obtained at the door two-feet in height from the garage floor at the time intervals mentioned earlier. Location two had the portable generator located in the same place with the garage door opened only one-foot from the fully-closed position. This placed the generator ten feet from the interior door leading from the garage into the living area of the structure. The CO-gas level measurement was obtained at the door two-feet in height from the garage floor at the time intervals mentioned earlier. Location three had the portable generator located on the front porch. The front porch was sixteen feet high, eight feet deep and ten feet wide with no screen enclosure at the entrance of this home. The generator was located nine feet from the front door leading into the home. The CO-gas level measurement was taken at the front door two-feet in height from the floor at the time intervals mentioned earlier. Location four had the portable generator located on the pool deck area on the far side of the pool from the home. The dimensions of this location are unable to be described here due to the changing angles of the architecture around the caged pool lanai. The closest opening to the home from the placement of the generator was a standard door leading from the living area to the pool that was eighteen feet from the portable generator. The CO-gas level measurement was obtained at this door four-feet in height from the lanai floor at the time intervals mentioned earlier. Location five had the portable generator located on the exterior of the home under a bedroom window. The generator was placed eleven feet from the bedroom window which was at a height of five feet from the ground. The CO-gas level measurement was obtained at the window ledge at five-feet in height at the glass of the window at the time intervals mentioned earlier. This research may have limitations in the ability to exactly replicate or duplicate this experiment elsewhere by the fact that this was conducted outside in an uncontrolled environmental setting.

Experiment 4

The forth generator experiment took place on August 10, 2006 at 17:00 within the boundaries of the city of Cape Coral at a single-family residence. The temperature was 94-degrees, winds southeast at 10 mph, 94 percent humidity, barometric pressure 28.00, and dew point 32 percent with thunderstorms threatening. The structure elevation was eight feet, seven inches above sea level located on an eighty by one-hundred-twenty-five foot residential lot. The home consisted of concrete-block exterior wall construction with stucco exterior surface. This structure had a two-car garage incorporated into the construction of the home with an interior door leading from the garage into the living area. The rear lanai was under the roof-truss system and had an aluminum framed screen enclosure. The rear lanai area had a double sliding-glass door accessing the living area of the home. All exterior windows were of standard glass.

Apparatus

The portable electrical generator used for the source of CO gas in this study was model YG-4000D, manufactured by Yamaha (see Appendix E). This portable generator was powered by 87-octane unleaded gasoline. Two of the generator outlets each had a fifty-foot standard electrical extension cord attached that powered two standard-type appliances; an upright freezer and a standard residential refrigerator. The atmospheric gas-monitor used in this study was supplied by the Cape Coral Fire, Rescue, and Emergency Management Service. The gas-monitor device was the M40 multi-gas monitor, manufactured by Industrial Scientific (see Appendix C) and measures the CO gas presence in the atmosphere by parts-per-million (ppm). The timed experiments utilized a standard digital stopwatch.

Procedure

Five sites were selected at this location to operate the portable generator and take CO-gas level readings at specific time intervals. Prior to starting the portable generator, the atmosphere was tested to make sure the presence of CO-gas was not present prior to beginning the test. After ensuring CO-gas was not present, the generator was started and CO-gas levels were measured at intervals of one, five, fifteen, and thirty minutes.

Location one had the portable generator located in on the garage floor with the garage door in the fully-open position. The generator was placed ten feet from the door leading into the living area from the garage. The CO-gas level measurement was obtained at the door two-feet in height from the garage floor at the time intervals mentioned earlier. Location two had the portable generator located in the same place with the garage door opened only one-foot from the fully-closed position. This placed the generator ten feet from the interior door leading from the garage into the living area of the structure. The CO-gas level measurement was obtained at the door two-feet in height from the garage floor at the time intervals mentioned earlier. Location three had the portable generator located on the front screened-in porch area. The front entryway dimensions were nine feet high, eleven feet deep and five feet wide; half of this area was enclose by screen. The generator was located nine feet from the front door leading into the home. The CO-gas level measurement was taken at the door two-feet in height from the floor at the time intervals mentioned earlier. Location four had the portable generator located on the rear patio lanai. The dimensions of the rear lanai were ten feet in height, fourteen feet deep and fourteen feet wide partially enclosed by screen. The placement of the generator was seven feet from the sliding glass door leading into the living area. The CO-gas level measurement was obtained at this sliding glass door four feet in height from the lanai floor at the time intervals mentioned earlier. Location five had the portable generator located on the exterior of the home under a bedroom window. The generator was placed ten feet from the bedroom window which was at a height of four feet, five inches from the ground. The CO-gas level measurement was obtained at the window ledge height. This research may have limitations in the ability to exactly replicate or duplicate this experiment elsewhere by the fact that this was conducted outside in an uncontrolled environmental setting.

Results

Four experiments related to operating portable generators in and around single-family residential structures were conducted as the basis of my original action research to be included in the final television program and answer the fourth research question. What is the minimum distance that a portable generator should be placed from the home to reduce the risk of accidental CO poisoning?

Experiment 1

The findings of the first generator experiment conducted on August 9, 2006 began at 08:01. Location one had a 2-ppm reading at one minute, 4-ppm reading at five minutes, 11-ppm reading at fifteen minutes, and 20-ppm reading after thirty minutes of continuous operation of the portable generator. Location two had a 4-ppm reading at one minute, 12-ppm reading at five minutes, 72-ppm reading at fifteen minutes, and 488-ppm reading with alarm after thirty minutes of continuous operation of the portable generator. Location three at one minute of operation had a 168-ppm reading with an alarm alerting the atmosphere was dangerously saturated with CO gas within the test area. The remaining CO sampling intervals were terminated for safety reasons due to the high-levels of CO gas present. Location four had a 0-ppm reading at one minute, 9-ppm reading at five minutes, 33-ppm reading at fifteen minutes, and a 147-ppm reading with alarm after thirty minutes of continuous operation of the portable generator. Location five had no detectable presence of CO gas at any time with a 0-ppm reading at one, five, fifteen, and thirty-minutes of continuous operation of the portable generator. A summary of findings in this experiment are located in table-format to assist in identification and comparison (see Appendix F).

Experiment 2

The findings of the second generator experiment conducted on August 9, 2006 began at 14:31. Location one had a 0-ppm reading at one minute, 8-ppm reading at five minutes, 9-ppm reading at fifteen minutes, and 8-ppm reading after thirty minutes of continuous operation of the portable generator. Location two had a 2-ppm reading at one minute, 18-ppm reading at five minutes, 60-ppm reading at fifteen minutes, and 350-ppm reading with alarm after thirty minutes of continuous operation of the portable generator. Location three at one minute of operation had a 182-ppm reading with an alarm alerting the atmosphere was dangerously saturated with CO gas within the test area. The remaining CO sampling intervals were terminated for safety reasons due to the high-levels of CO gas present. Location four had a 0-ppm reading at one minute, 2-ppm reading at five minutes, 2-ppm reading at fifteen minutes, and an 8-ppm reading after thirty minutes of continuous operation of the portable generator. Location five had no detectable presence of CO gas at any time with a 0-ppm reading at one, five, fifteen, and thirty-minutes of continuous operation of the portable generator. A summary of findings in this experiment are located in table-format to assist in identification and comparison (see Appendix G).

Experiment 3

The findings of the third generator experiment conducted on August 10, 2006 began at 09:31. Location one had a 0-ppm reading at one minute, 0-ppm reading at five minutes, 0-ppm reading at fifteen minutes, and 3-ppm reading after thirty minutes of continuous operation of the portable generator. Location two had a 0-ppm reading at one minute, 9-ppm reading at five minutes, 22-ppm reading at fifteen minutes, and 109-ppm reading with alarm after thirty minutes of continuous operation of the portable generator. Location three at one minute of operation had a 0-ppm reading, 0-ppm reading at five minutes, 3-ppm reading at fifteen minutes, and 2-ppm reading after thirty minutes of continuous operation of the portable generator. Location four had no detectable presence of CO gas at any time with a 0-ppm reading at one, five, fifteen, and thirty-minutes of continuous operation of the portable generator. Location five had no detectable presence of CO gas at any time with a 0-ppm reading at one, five, fifteen, and thirty-minutes of continuous operation of the portable generator. A summary of findings in this experiment are located in table-format to assist in identification and comparison (see Appendix H).

Experiment 4

The findings of the fourth generator experiment conducted on August 10, 2006 began at 17:01. Location one had a 0-ppm reading at one minute, 4-ppm reading at five minutes, 3-ppm reading at fifteen minutes, and 7-ppm reading after thirty minutes of continuous operation of the portable generator. Location two had a 5-ppm reading at one minute, 22-ppm reading at five minutes, 81-ppm reading at fifteen minutes, and 520-ppm reading with alarm after thirty minutes of continuous operation of the portable generator. Location three at one minute of operation had a 188-ppm reading with an alarm alerting the atmosphere was dangerously saturated with CO gas within the test area. The remaining CO sampling intervals were terminated for safety reasons due to the high-levels of CO gas present. Location four had a 202-ppm reading with an alarm alerting the atmosphere was dangerously saturated with CO gas within the test area. The remaining CO sampling intervals were terminated for safety reasons due to the high-levels of CO gas present. Location five had no detectable presence of CO gas at any time with a 0-ppm reading at one, five, fifteen, and thirty-minutes of continuous operation of the portable generator. A summary of findings in this experiment are located in table-format to assist in identification and comparison (see Appendix I).

The final product of this action research project was the creation of a thirty-minute governmental cable-television program to reduce the community's risk of CO poisoning from the use of portable generators. To abide by the format required of this project, this program will be briefly discussed and summarized here in this section; as the television program is unable to be included as an appendix. The taping of the actual cable-television program related to this project was on August 24, 2006 at Pro-One

Media located in Cape Coral, Florida. The television program was included into a monthly cable television program format, sponsored by the Cape Coral Fire, Rescue, and Emergency Management Service called, Public Safety First. The show is hosted by Ellen Davis, who is the Emergency Management Coordinator (EMC) for the organization. Accompanying this author on the show was Allan Carter, who is a lieutenant in the fire prevention division of the organization. The theme of this cable television program focused on three general areas of portable generators; events surrounding the impact of Hurricane Charley in 2004; the inherent dangers of portable generators; and how to safely use a portable generator. Prior to the taping of the show, two camera technicians from Pro-One Media of Cape Coral, Florida filmed various footage of the actual generator experiments being conducted for this research study for inclusion and use in the taping of the television program. The format of the show was a question-answer session hosted by EMC Ellen Davis. EMC Ellen Davis would ask a general question related to portable generators and either Allan Carter or this author would answer the question with specific details or facts related to each question. The program included the findings of the literature review of this study, as well as, incorporating the findings of this original research project. The show emphasized four main points to the viewers; read the entire owners/operating manual of the portable generator and follow the instructions; never place a generator indoors or in an area that has a ceiling or roof; operate the generator outside at a minimum distance of fifteen feet from any opening into the home; and finally to buy and install carbon monoxide detectors that have battery backup. These four key items related to the portable generator program were emphasized throughout the entire program. The show will be broadcast continually on a varying schedule on the local governmental cable channel throughout the hurricane season with additional showings more frequently with storm-threats or post-storm strikes.

Discussion

In this study, the specific CO-level measurements found in location two of each of the four experiments were similar in the findings of previous studies where a portable generator was operating within an enclosed space (see Daley et al. 2000, CPSC: May 20, 2004, and Shouldis 2004).

The results discovered in all of the experiments identified as location-one were found to have lower readings of CO gas levels than anticipated. Location-one had the portable generator operating inside the garage with the door in the fully-open position. Because this location had the generator operating under the ceiling area of the garage it was hypothesized that ventilation would be inadequate and a deadly buildup of CO gas would be discovered. However, the data revealed that operating the generators in the garage with these door fully-open suggested that dangerous levels of CO gas had not accumulated as hypothesized. Even at these lower-levels, CO was still present and over time would be more of a factor as the United States Environmental Protection Agency (EPA, 2000), has established that residential levels of CO are not to exceed 9ppm over an eight-hour average. Reflecting on the data in all of the open garage cases and the procedures used has led to two possible theories believed to influence these lower than expected CO levels measurements. First, the generator may not have been allowed to operate for a time-period sufficient to allow the CO to build up to a higher concentration as might be the case after hours of continuous operation. The second possible cause may be that the height of measurement of only two feet was too low to accurately read what may have been accumulating higher in the atmosphere of the garage area. These two possible explanations were hypothesized after analyzing the data and the procedures involved in setting up the experiments.

There were slight variations in the exact measurement of CO gas recorded at each experiment identified as location-two; however, all had reached potentially lethal levels after just twenty minutes of continuous operation. In one study by the CDC (March 10, 2006) half of the incidents involving CO poisoning from portable generators had the device placed outside the home; not enclosed by a roof or walls with an average distance of 3.2 feet away from the home. The findings of this research study support those discovered in the above CDC report, as readings as far as ten feet away from the home could still find detectable levels of CO present in some experiments. Over time, even low levels can cause signs and symptoms of mild CO poisoning. No portion of this study included running a generator anywhere in the living area of the home as the previous study conducted by the CPSC (May 20, 2004) demonstrated the rapid development of lethal CO gas when generators are operated inside a home explain why victims are frequently found dead or severely poisoned within a few hours or from overnight exposures after being missed by family, friends or co-workers.

The operation of the generators on the screened front porches of experiments one, two and four resulted in surprisingly high concentrations of CO gas after only one-minute of operation. Within this first minute of each test, the generator had already dangerously saturated the immediate atmosphere of the porch with enough CO gas at lethal levels that if allowed to continue would have entered the living areas of the homes. It is theorized that the screen enclosure actually prevented ventilation in the front entryway and trapped the CO gas which allowed the rapid buildup of deadly CO gas that required the experiment to be terminated prematurely due to safety reasons.

The final data associated and obtained from this research project indicated that no detectable measurement of CO gas could be obtained when the generator was operated outside the home at a distance greater than ten feet. In major power outage situations, doors and windows will be opened in Florida to combat the stifling heat; which also allows avenues for deadly CO gas to enter the home. When a generator is operated too close to these openings or a window-mounted air conditioner, CO gas can easily access the interior of the home. For this reason, the findings of this study will be implemented within the Cape Coral Fire, Rescue, and Emergency Management Service as establishing fifteen feet as the recommended minimal distance that a generator should be operated on the exterior of a home from any opening (Appendix A). The organizational implication for this study is that the Cape Coral Fire, Rescue, and Emergency Management Service is now advising any resident who operates a portable generator at their home to be a minimum of fifteen-feet from any opening based on the research findings of this study. If questioned how the organization determined fifteen feet to be the minimal safe operating distance; the reply will be that it was based on actual studies conducted using portable generators to determine the final distance. The final product of this research effort was the taping of the cable television program at Media One in Cape Coral, Florida related to portable generators. During this show the findings and recommendations related to operating a portable generator on the outside of the home fifteen feet from an opening was a major theme repeated often during the program. Additionally, the findings related to this study will also be incorporated into future educational events surrounding hurricane preparedness seminars, public education literature and training of fire fighting personnel.

The implications of the results discovered in this research project may have long-lasting benefits to the community and organization as well. The results will be used in a new approach using the media of a television program to reach the residents about educating them to the dangers of portable generators and CO poisoning. If successful in educating the public in this television program of the dangers of CO and portable generators, the organization could benefit by having a reduced workload following a disaster-type event in searching for improperly placed portable generators.

Recommendations

The recommendations related to this study are provided to reduce the needless loss of life and injury to residents from CO poisoning from improper placement of portable generators which was the original purpose of this research project. In addition, the recommendations are designed to address the original research questions as well. The first recommendation for the Cape Coral Fire, Rescue, and Emergency Management Service is to make sure that when a major power disruption occurs; that post-storm reconnaissance teams are immediately deployed into the community to begin searching for improper placement of generators and to distribute an informational handout related to their use (Appendix A). The deployment of specialty inspection teams searching for portable generators should continue throughout the entire power outage time-period and canvass all areas of the community again and again as citizens may purchase a generator at any time after the power outage. An early notification and monitoring method similar to this proved successful in Puerto Rico during Hurricane Georges in 1998 and is believed to have reduced the occurrence of CO incidence related to this storm (see CDC October, 1998). The numerous cases studies by the CDC (1993, 1998, 2004, 2005 and 2006) indicate that CO poisoning should be expected following a major disaster that disrupts electrical power.

The increase in generator purchases (see Daley, Smith, Paz-Argandona, Malilay, and McGeehin, 2000 and CPSC, April 12, 2004) will also increase the number of inexperienced owners increasing the likelihood of improper placement and operation when the next disaster strikes. Educated with this new research knowledge, the Cape Coral Fire, Rescue, and Emergency Management Service should expect and prepare for a greater number of operating generators within the community than was encountered during Hurricane Charley in 2004. Based on the expectation of increasing numbers in generator sales and population growth in Cape Coral, it is further recommended that the Cape Coral Fire, Rescue, and Emergency Management Service purchase additional personal air monitoring devices for additional specialty teams searching and measuring for the presence of CO gas before the next disaster strikes.

With the new findings related to this study, it is recommended that training should be conducted for all employees of the organization to educate and enhance their ability to recognize improper generator placement when found closer than fifteen-feet to any structure opening. Additionally, fire personnel should receive additional medical training in recognizing the signs and symptoms associated with CO poisoning in humans who are commonly missed or misdiagnosed by emergency response professionals and other medical professionals (Vajani et al., 2005; Montagna, 1996, 2003).

The final recommendation would be for the City of Cape Coral to consider possibly enacting a local ordinance for CO detectors for all residential residences which would require both electrical and battery backup power source similar to that of Mecklenburg County, North Carolina (see CDC March 12, 2004) to reduce the risk of CO poisoning by commercially available detection devices. With the inability of humans to detect the presence of CO gas, such an ordinance would be the final defense to prevent CO poisoning when education, notification, and post-storm reconnaissance methods have failed.

In summary, this research project has furthered the knowledge of identifying the minimal distance required to safely operate a portable generator near openings outside the home. Future researchers should endeavor and research realistic environmental models related to minimal safe operating distances for portable generators. In addition, technology advancements should be researched to reduce the emission of CO from portable generators and further research possible alternate energy sources and fuels that can be harnessed in power outage situations that do not endanger the public with the release of CO gas when operating a portable generator.

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